

MSC Guidelines for Review of Circuit Breaker Coordination Study

Procedure Number: E2-04

Revision Date: 11/04/2010



S. J. Kelly, CDR, Chief Engineering Division

References:

- a) 46 CFR 111.51 – Coordination of Overcurrent Protective Devices
 - b) Navigation and Inspection Circular (NVIC) 2-89, “Guide for Electrical Installations on Merchant Vessels and Mobile Offshore Drilling Units”, can be found at: <http://www.uscg.mil/hq/cg5/nvic/pdf/1989/n2-89.pdf>
 - c) American Bureau of Shipping (ABS), “Rules for Building and Classing Steel Vessels 2003, Part 4, Vessel Systems and Machinery”.
 - d) Safety Of Life at Sea (SOLAS), 1974 with amendments to date
 - e) ANSI/IEEE Std 242, “IEEE Recommended Practice for Protection and Coordination of Industrial and Commercial Power Systems”, 2001
 - f) IEEE Std 141, “IEEE Recommended Practice for Electric Power Distribution for Industrial Plants”, 1993
 - g) Cooper Bussmann, “Part 2. Selective Coordination of Overcurrent Protective Devices for Low Voltage Systems”, Bulletin EDP-2 (2004-2)
 - h) MSC Plan Review Guidelines: E2-06, Load Analysis; E2-07, One Line Diagram; E2-19, Short Circuit Analysis.
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Contact Information:

If you have any questions or comments concerning this document, please contact the Marine Safety Center by e-mail or phone, referring to Procedure Number **E2-02**

E-mail: MSC@uscg.mil

Phone: 202-475-3402

Website: <http://homeport.uscg.mil/MarineSafetyCenter>

Responsibilities:

Using applicable portions of references (a) through (h), the submitter shall provide sufficient documentation and plans to indicate compliance with the applicable requirements. This includes circuit breaker coordination analysis for each generator power distribution system that ensures continuity of service to equipment vital to propulsion, control, or safety of the vessel under short circuit conditions by coordination and selective operation of overcurrent protective devices. For a typical coordination study, documentation should include details on short circuit calculations, one line diagrams, switchboards, generators and protective device characteristics. To facilitate plan review and project management, all plans and information specified in these guidelines should be submitted as one complete package through a single point of contact for the project. All submissions mailed to MSC shall be made in triplicate.

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General Guidance:

- Vessel submittals must include the following applicable plans:
 - AC/DC electrical one line diagram
 - Short circuit current calculations for an aggregate generating capacity below 1500 KW, see 46CFR 111.52-3 or
 - Short circuit current calculations for an aggregate generating capacity above 1500 KW, see 46CFR 111.52-5
 - AC/DC load analysis
- Ensure that review of the above plans has been satisfactorily conducted as calculation of short circuit currents is the basis of the coordination analysis.
- A coordination analysis review requires availability of the following information:
 - From the short circuit analysis submittal, locate the point or points on the one line diagram which indicate the locations of the faults considered in the short circuit study.
 - A summary that lists the maximum generator capacity available (to include simultaneous parallel generator operation as applicable) plus the largest probable motor load currents that are directed to a zero-impedance (bolted) three-phase fault. The calculated fault currents can then be placed at the corresponding fault points in the electrical one-line. This will then provide the necessary data to properly conduct an upstream vs. downstream circuit breaker coordination analysis.

Determination of Adequate Selectivity or Coordination Per 46CFR 111.51-3:

- A fault in a branch circuit that is not vital to vessel propulsion, control or safety will not also trip an equipment branch circuit that is vital.
- A fault in a branch circuit vital to vessel propulsion, control or safety is cleared by the protective device closest to the point of the fault, e.g.
 - Protective devices are rated and adjusted such that a device nearest to the fault will trip open to isolate the faulted circuit from the remainder of the vessel's power system; thus, providing maximum power system continuity.
 - In a low-voltage system (except for relays and in certain fuse applications) circuit breaker coordination is usually obtained via a log-log plot display of two or more circuit breaker time-current characteristics. For individual circuit breakers operating in series, optimum coordination is achieved if an open area exists between individual circuit breaker characteristics. See Drawing No. 2, time-current characteristic curves which overlap will not coordinate.

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General Guidance (continued):

- Circuit breakers with magnetic or instantaneous trips will only coordinate with each other if there is adequate impedance between them such that the maximum available short circuit current at the downstream circuit breaker is less than the instantaneous trip setting of the upstream circuit breaker. Selectivity by impedance in the circuit, see drawing No. 2.
- Circuit breaker coordination is usually possible (regardless of impedance between the circuit breakers) if upstream circuit breakers have only short time delay trips. This is referred to as selectivity by circuit breaker time delay, see drawing No. 3.
- Protective devices are set or adjusted such that pickup current and operating time is short, but sufficient to override system transient overloads such as inrush currents due to motor starts.
- The coordination of overcurrent protective devices should be demonstrated for all potential plant configurations, see 46 CFR 111.51-3.
- A coordination study submittal must be plotted on log-log graph paper. The ordinate scale will represent *time*, and generally indicates a 5 decade logarithmic scale ranging from 0.01 to 1000 seconds. The abscissa represents *current level* and indicates a 4 1/2 decade logarithmic scale that contains the following information at the fault location of interest:
 - Cable heating limit curve (or cable damage curve) is necessary if cables are small and levels of fault current are high.
 - Transformer magnetizing inrush current. Currents for 500 to 2500kVA transformers are approximately 8 to 12 times the transformer full load current for a period of 0.1 second. Currents for transformers above 2500kVA are approximately 20 to 25 times the transformer full load current for a period of 0.1 second.
 - ANSI transformer protection curve (Z-curve)
 - Generator decrement curve.
 - Time-current characteristic curves on all protective devices (i.e. circuit breakers, relays, and fuses) must be identified.
 - Interrupting rating of each protective device.
 - Maximum available short circuit current at the particular fault point under review.

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General Guidance (continued):

- Motor characteristic curves including inrush current, locked rotor current, acceleration time, allowable stall time and full-load current, see drawing No. 1. Motor inrush current calculation is determined by the following:
$$I \text{ amps (inrush)} = I \text{ amps (locked rotor)}(1.6)(1.1)$$

Where 1.6 = offset multiplier; and 1.1 = safety multiplier

Notes: a. Transition between inrush and locked rotor is approximately 0.1 second.

b. Transition between locked rotor and full load current terminates at the acceleration time, and is usually plotted at between 5-10 seconds.
- Identification of individual time current curve elements.
 - A title block to identify the time current curve plot.
 - A legend to identify the various elements, including the manufacturer, model/type, and specified settings.
 - A segment on the electrical one line should be drawn on the coordination graph indicating element locations, see drawing No. 2.
- Randomly note several individual fault points on the one line diagram and analyze coordination or selectivity of upstream/downstream overcurrent protective devices for that particular fault in the coordination study submittal.
- Margins for Proper Coordination:
 - Induction disc overcurrent relays, see drawings No. 4A & 4B.
 - Transformer protection, see drawing No. 5
 - Induction motors, see drawing No. 6
 - Recommended margins for combination circuit breakers, fuses and relays; see Drawing No. 7
 - The instantaneous trip of a generator circuit breaker must be set above, but as close as practicable to, the maximum asymmetrical short circuit available from any one of the generators that can be paralleled. Please see 46CFR 111.12-11(e).

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General Guidance (continued):

- Compromise in Protective Device Settings:
 - Proper protective device coordination requires accurate determination of the characteristics of individual protective devices as shown in drawing No. 7. However, there may be submittals where the device settings indicated do not provide optimum coordination. For example:
 - a. Characteristic Mismatch: Characteristic curves of similar devices can vary between manufacturers. Some curves may exhibit a varying wide sweep from pickup current to the instantaneous trip setting. To avoid curve overlap, the adjacent upstream circuit breaker may need to be set undesirably high which may not provide long-time protection to cables or circuit breakers. Therefore, the options may be to accept some slight overlap, or recommend another protective device with compatible characteristics.
 - b. Single Large Feeder Load: Some circuits power a large motor along with a number of small motors. Proper coordination is based on the largest motor load, and as such, the setting of the protective device may be as high as settings on the adjacent upstream device. Therefore some device characteristic overlap may need to be considered, or a need for another protective device that can provide adequate coordination.
 - c. Oversized Protective Devices: Over estimation of circuit loads may result in protective devices with current ratings that significantly exceed actual load currents. Thus, a poor level of protection with pickup settings that exceed desired load levels. Due to higher pickup settings, a fault may result in greater load damage. Settings of protective devices should match circuit load currents. Please see 46CFR Subparts 111.53 and 111.54. Therefore, to provide proper load protection, a protective device may need to be replaced.
 - Compromises may be required between circuit protection and service continuity. If applied with sound judgment, it should result in improved system protection.

Attachments:

1. Dwg. No. 1, Motor Benchmarks
2. Dwg. No. 2, Selectivity by Impedance in the Circuit
3. Dwg. No. 3, Selectivity by Time Delay in the Circuit Breaker
4. Dwg. No. 4A, Over Current Relay Margins
5. Dwg. No. 4B, Over Current Relay Margins
6. Dwg. No. 5, Transformer Protection
7. Dwg. No. 6, Induction Motors
8. Dwg. No. 7, Recommended Margins

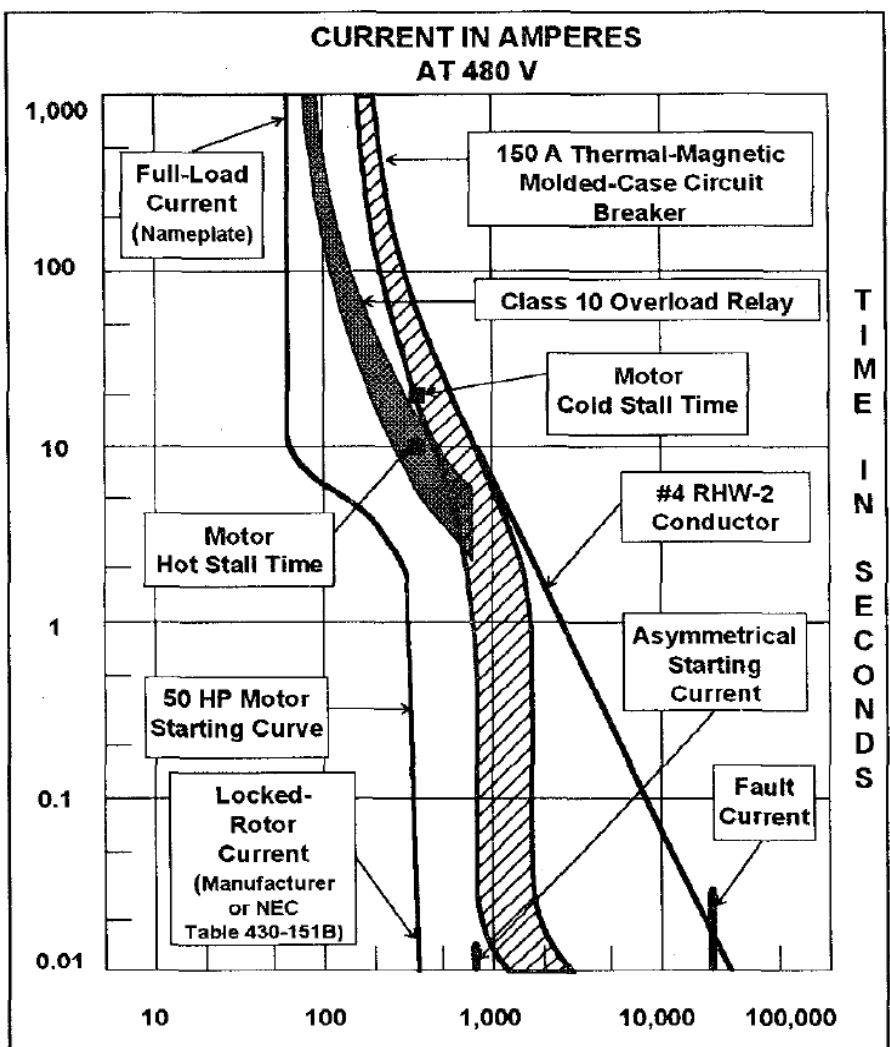
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Disclaimer:

This guidance is not a substitute for applicable legal requirements, nor is it itself a rule. It is not intended to nor does it impose legally-binding requirements on any party. It represents the Coast Guard's current thinking on this topic and may assist industry, mariners, the general public, and the Coast Guard, as well as other federal and state regulators, in applying statutory and regulatory requirements. You can use an alternative approach for complying with these requirements if the approach satisfies the requirements of the applicable statutes and regulations. If you want to discuss an alternative, you may contact the Marine Safety Center, the unit responsible for implementing this guidance.



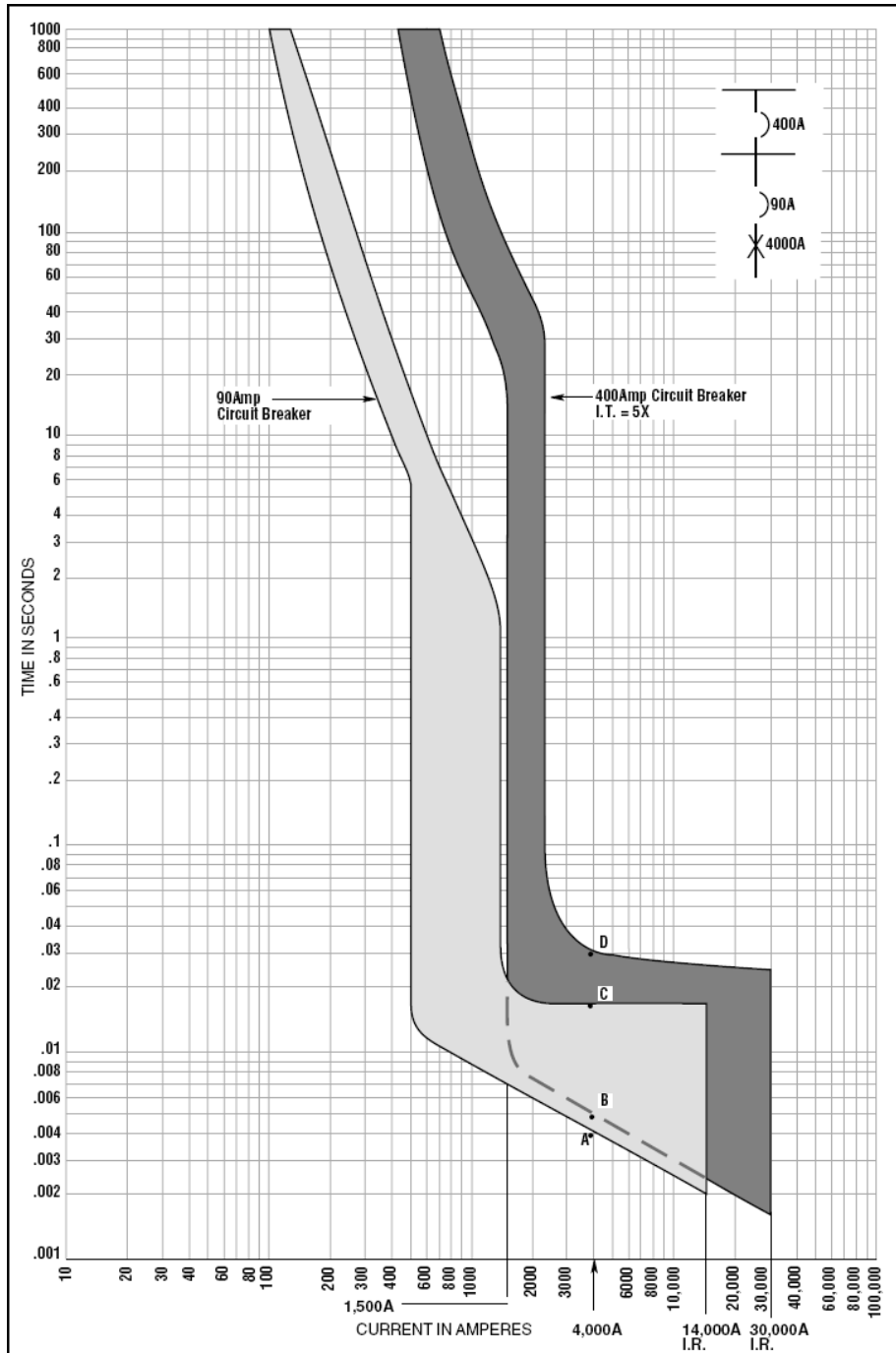
Dwg. No. 1, Motor Benchmarks

(Ref. (e) Figure 10-4)

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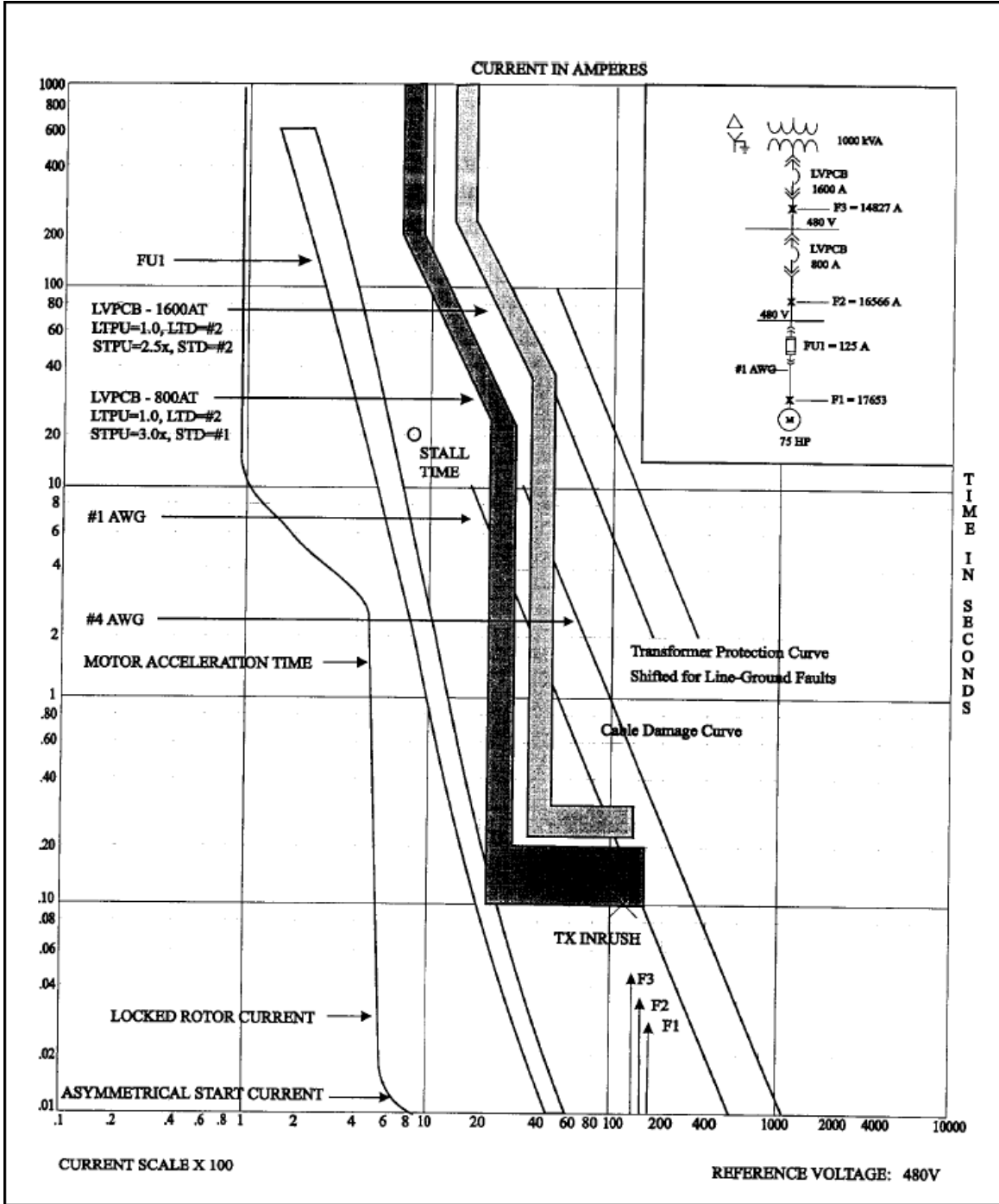
Dwg. No. 2, Non-Selective Breaker Coordination

(Ref (g) Figure 10)

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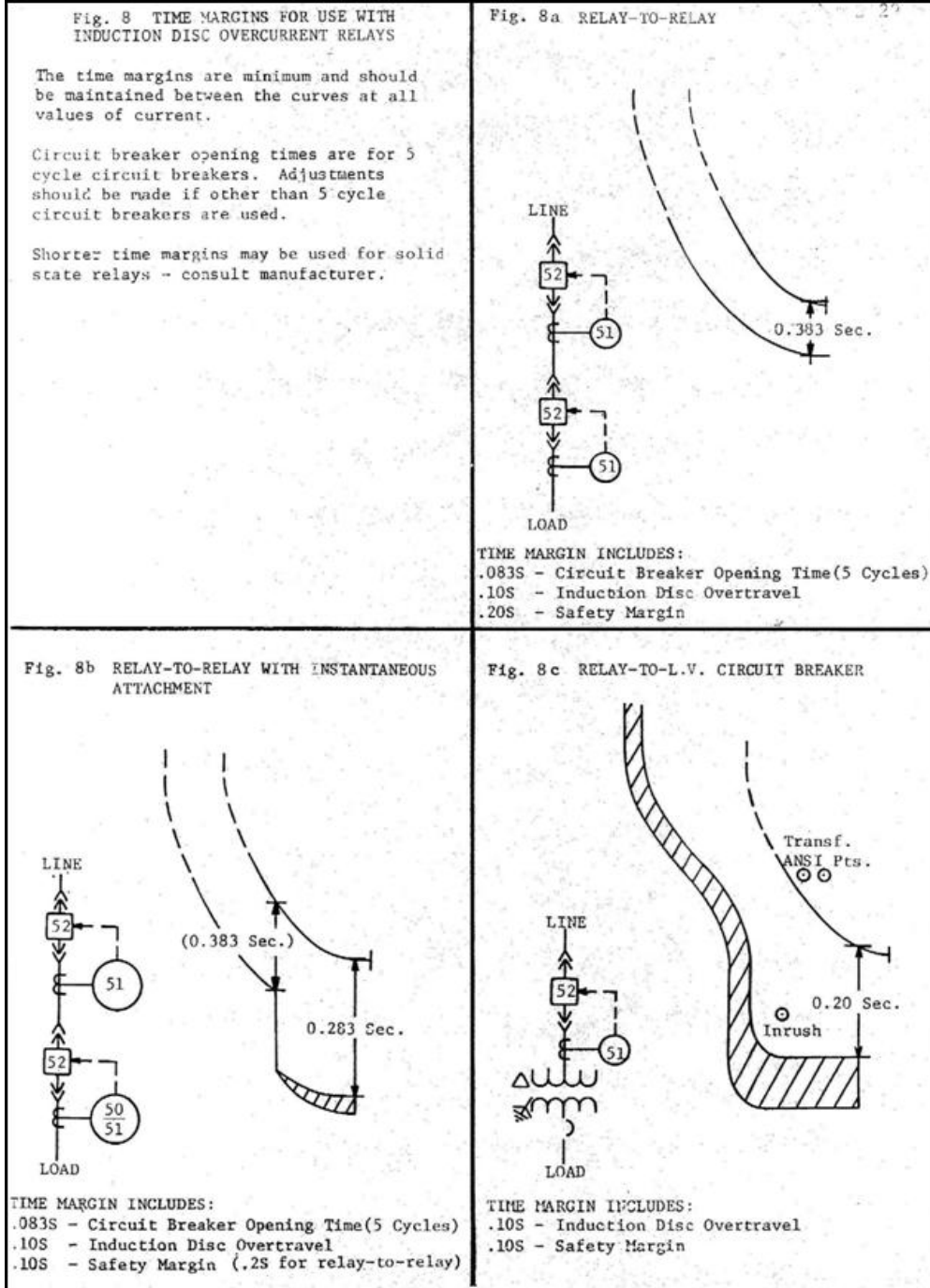
Dwg. No. 3, Selective Breaker Coordination

(Ref (e) Figure 15-16)

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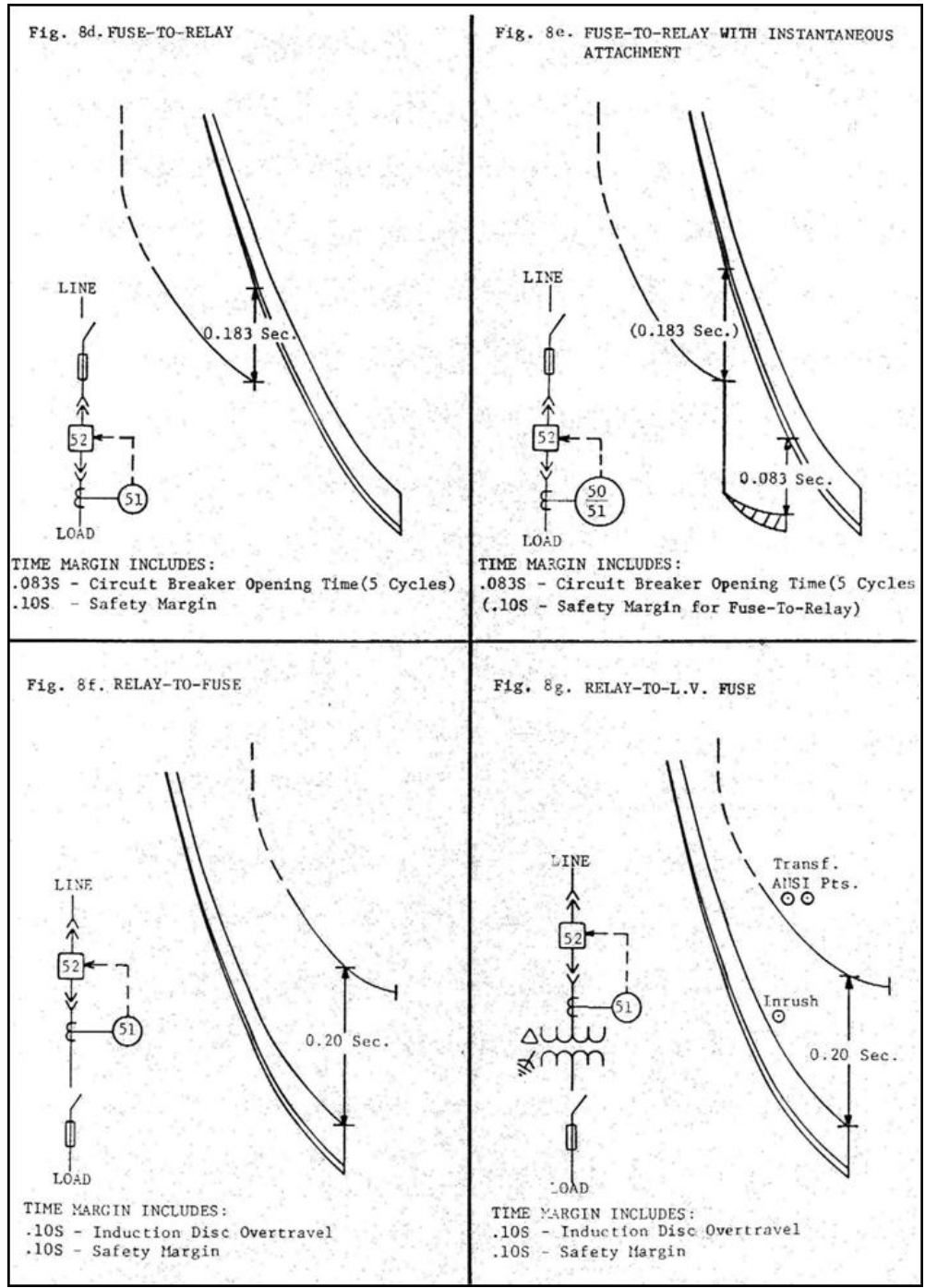


Dwg.No. 4A, OC Relay Margins
(MSC Drawing)

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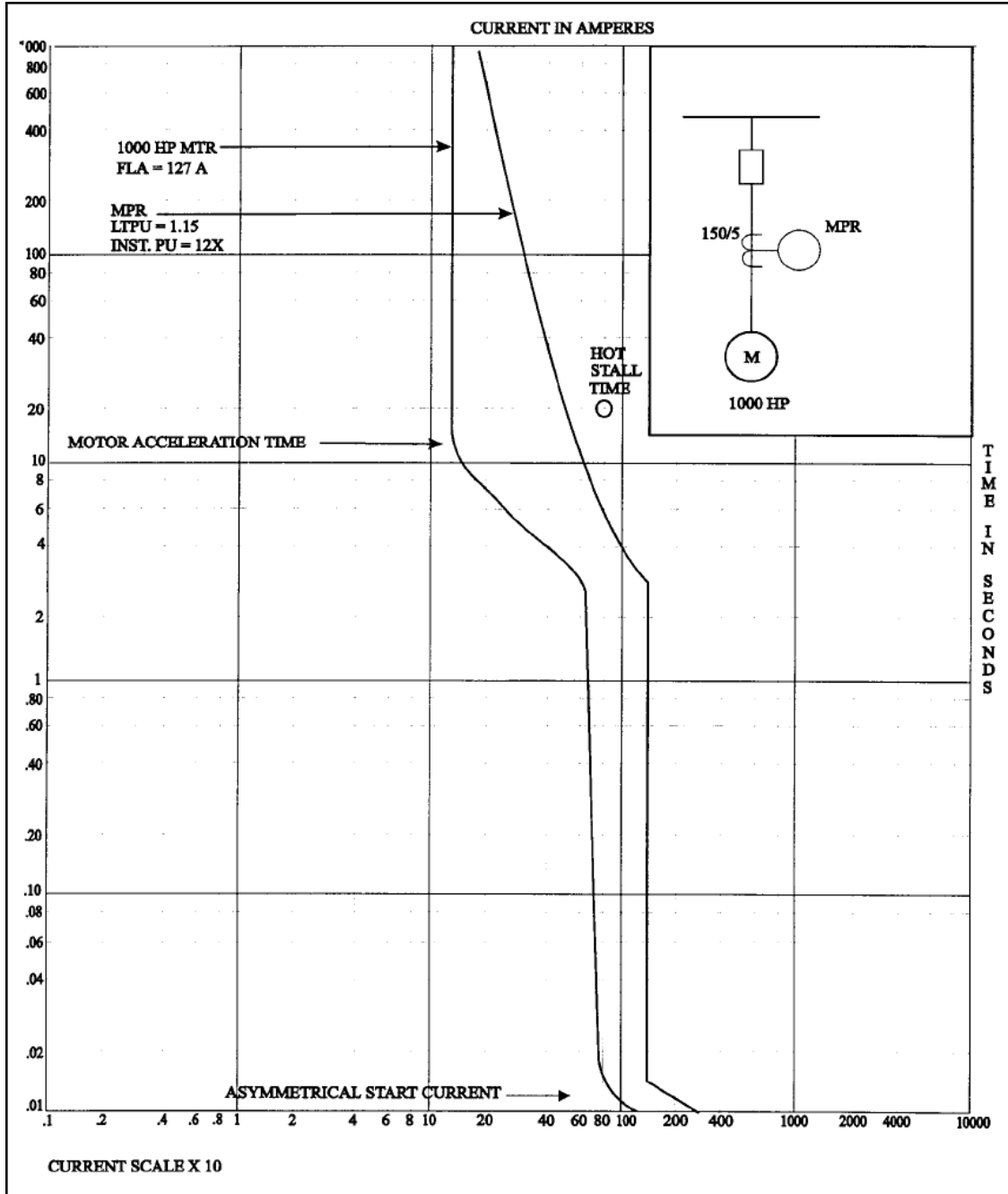


Dwg.No. 4B, OC Relay Margins
 (MSC Drawing)

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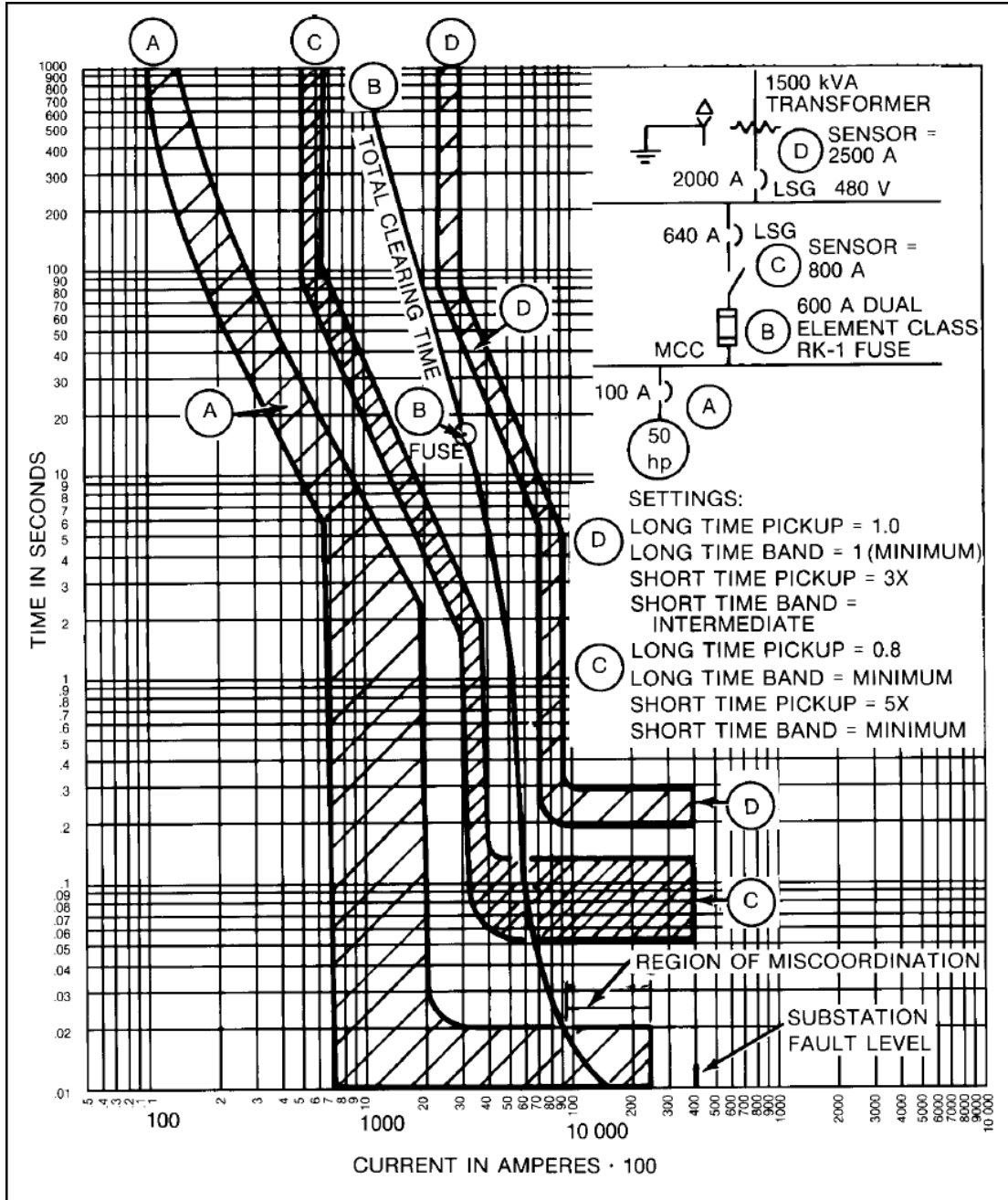


Dwg. No. 6, Induction Motors
(Ref (e) Figure 15-11a)

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Dwg. No. 7, Recommended Margins

(Ref (e) Figure 15-28)